

Measurement Of Students Attitude Towards Statistics: A Mokken Scales Analysis Of Its Dimensions

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ABSTRACT

Nowadays, almost all curricula in the social sciences contain at least one course in statistics, given the importance of this discipline as a basic knowledge to understand the modern world. It's necessary reflects on the student's attitude to statistics, because it's could be an obstacle or an advantage in their learning process. To measure the student's attitude and incentives about statistics, we use a test (Bayot et al., 2005), related to other ones which exists in the specialized literature, that identifies the latent factors relating to students' motivation and attitude towards statistics. This paper describes the formal and metric characteristics of the non-parametric model of item response theory for the latent factors using an extension of Mokken scales analysis.

Keywords: Learning Statistic; Latent factors; Non-Parametric Item Response Model; Mokken Scales Analysis

INTRODUCTION

The influence of cognitive and affective factors in the students' attitude and performance in the learning of statistics has been widely discussed in the literature (Roberts and Saxe, 1982; Beins, 1985; Wise, 1985; Katz and Tomezik, 1988; Gil, 1999; Bayot *et al.*, 2005; Mondéjar, Vargas and Bayot, 2008; Mondéjar and Vargas, 2010). However, there is still no consensus on the theoretical foundation of this influence (Carmona, 2004), nor on how to operationalize concepts that have different shades and are not directly observables. Following Auzmendi (1992, p. 17), we mean attitudes as "aspects are not directly observable but inferred, made both by the beliefs and the feelings and behavioral predispositions toward the object at that address". The most important attitudes are those of the affective component—the domain in which researchers have shown most interest. Several works study the anxiety construct in education and its relation with academic performance (Seipp, 1991; Hardy and Hagtvet, 1996), and show that modify the students' level of anxiety can translate into improved academic performance.

In this paper, we use a questionnaire about attitude towards statistics developed in Bayot *et al.* (2005), which decomposes attitude into two subscales, one affective and the other evaluative, both bi-dimensional in structure. In the affective subscale, one factor measures the degree of interest in the subject, and the other, the level of students' anxiety when tackling statistics problems. The valorative subscale also consists of two components, one measuring the utility students perceive for their current studies, and the other, the utility for their future professional career. This latent structure is similar to other scales proposed in the literature (Wise, 1985; Waters *et al.*, 1988; Elmore and Lewis, 1991; Woehlke, 1991; Auzmendi, 1992; Schau *et al.*, 1995; Gil, 1999; Darias, 2000). In these works, the structure always contains factors relating to both the affective and evaluative components, but they tend to disagree on the number of variables they use to operationalize each component. Searching out existing standard scales and measures for constructs is therefore often an important early step in the research process.

While in the education literature are not consensus on how to operationalize these constructs (often there is no one perfect way to operationalize its), the developed scales should be validated and their psychometric characteristics analysed. If scales are defined as sets of items which stand in ordinal relationship to each other, then Mokken scales meet this test of ordinality between items. In this case, the coefficients of scalability and reproducibility are tests of whether items are sufficiently in an ordinal relationship to justify their combination in an index (Mokken and Lewis, 1982). Loevinger's coefficient H measures the conformity of a set of items to Mokken's criteria and validates their use together as a scale of a unidimensional latent variable (Sijtsma and Verwey, 1992).

The aim of this paper is to evaluate the quality metrics of the used questionnaire for measuring students' attitudes towards statistics, adapted to the proposed structure. Specifically, each of the four dimensions should consist of items that are added one-dimensional and which satisfy the monotonous uniformity. To this end, we apply a nonparametric item response model which generalizes that of Mokken (Mokken, 1971, 1997), called strong model of double monotony (Sijtsma and Hemken, 1998), given the nature of the data obtained by the Bayot *et al.* questionnaire.

DATA COLLECTION AND METHOD

The empirical study uses a sample of 374 students from the University of Castilla-La Mancha (Spain) enrolled on a unit with statistical content for the first time during their university studies. The study has an ex-post-facto design, and took place in the second week of classes, in order to ensure that the results were not biased by factors such as the progress of the unit, the performance of the teacher, or the partial results obtained.

Mokken model, and its derivatives, assuming the existence of a latent scale (θ) related to the empirical scale used as measure (X), usually obtained by adding the scores of each of the items. But it needs some metric conditions to ensure the inferences made based on the first by the second (Elosua, 2006):

- Stochastic Ordering of Empirical Scale (SOES). The order of individuals on the latent scale produces a stochastically correct order on the empirical scale. Given two individuals, A and B, with levels in the latent scale θ_A and θ_B such that $\theta_A < \theta_B$, this property states that for any empirical score x:

$$P(X \geq x / \theta_A) \leq P(X \geq x / \theta_B)$$

- Stochastic Ordering of Latent Scale (SOLS). The order of individuals on the empirical scale produces a stochastically correct order of individuals on the latent scale. For a constant value in the latent variable (s) and for two empirical values x_1 and x_2 such that $x_1 < x_2$:

$$P(\theta > s / X=x_1) < P(\theta > s / X=x_2)$$

The evaluation of these conditions is based on empirical verification of some properties. The monotony can be assessed by the Loevinger's scalability coefficient, H_{ij} :

$$H_{ij} = 1 - \frac{\sum_i \sum_j w_{ij} n_{oij}}{\sum_i \sum_j w_{ij} n_{eij}}$$

where w_{ij} is the number of errors in the pattern ij, n_{oij} is the number of responses observed in the response pattern ij and n_{eij} is the number of expected responses in the pattern ij under the assumption of independence.

Although there is a test for evaluate their significance (Molenaar and Sijtsma, 2000), because of low power, it is usual to consider values equal to or above 0.3 as significant (Mokken, 1971).

STATISTICAL RESULTS

To evaluate the psychometric properties of the questionnaire on attitudes towards statistics of Bayot *et al.* (2005), we have estimated the coefficients of scalability, H_i , by the software routine Mokken for statistical software R.

Table 1 shows factorial structure of the questionnaire, obtained by factorial analysis (Mondéjar and Vargas, 2010). Each empirical scale is estimated by aggregation of items, weighted by rotated factor loadings.

Table 1: Rotated Factor Loadings

Item	F1: Interest	F2: Anxiety	Item	F3: Pres. Util.	F4: Proff. Util
Item n° 15	0.764		Item n° 10	0.690	
Item n° 17	0.759		Item n° 25	0.655	
Item n° 14	0.737		Item n° 16	0.593	
Item n° 13	0.735		Item n° 3	0.533	
Item n° 24	0.671		Item n° 5		0.746
Item n° 18	0.537		Item n° 20		0.679
Item n° 9		0.735	Item n° 11		0.555
Item n° 7		0.722	Item n° 26		0.552
Item n° 22		0.706	Item n° 6		0.550
Item n° 21		0.702	Item n° 4		0.520
Item n° 23		0.643	Item n° 2		0.519
Item n° 12		0.633	Item n° 19		0.501
Item n° 1		0.557	Item n° 27		0.497

To assess the monotonicity of the four empirical scales, Loevinger's scalability coefficients, H_{ij} , were estimated for each pair of items. From them, we obtain the scalability coefficients for each item, H_i , adding the corresponding H_{ij} for all other items, as shown in Table 2:

Table 2: Loevinger's Scalability Coefficients H_i

Item	F1: Interest	F2: Anxiety	Item	F3: Pres. Util.	F4: Proff. Util
Item n° 15	0.587		Item n° 10	0.433	
Item n° 17	0.600		Item n° 25	0.383	
Item n° 14	0.594		Item n° 16	0.409	
Item n° 13	0.565		Item n° 3	0.369	
Item n° 24	0.543		Item n° 5		0.295
Item n° 18	0.426		Item n° 20		0.283
Item n° 9		0.469	Item n° 11		0.438
Item n° 7		0.450	Item n° 26		0.492
Item n° 22		0.492	Item n° 6		0.420
Item n° 21		0.491	Item n° 4		0.449
Item n° 23		0.417	Item n° 2		0.444
Item n° 12		0.418	Item n° 19		0.317
Item n° 1		0.378	Item n° 27		0.382

Finally, we estimate the scalability coefficients for each empirical scale adding the H_i for the constitutive items. Table 3 shows, for each factor, the Loevinger's coefficients H , and the empirical mean and standard deviation.

Table 3: Coefficient H, Mean and Standard desviation of escales

Scale	H	Mean	Standard Desviation
F1: Interest	0.5555	2.56	0.92
F2: Anxiety	0.4469	3.26	1.00
F3: Present utility	0.3979	3.40	0.98
F4: Professional utility	0.4213	3.47	0.93
Total of escales		3.17	0.96

In all cases, the scalability coefficients are significant, indicating that the obtained empirical scales adhere to the principle of monotonicity. This ensures the one-dimensionality for the empirical scales, reflecting the existence of latent scales for each of the dimensions analyzed (Junker and Sijtsma, 2000).

In a descriptive analysis of the scales, we note the low level of interest in statistics, they find most useful for their future careers than for their present studies. Also, the raised level of anxiety in students is above the central value of the scale.

CONCLUSIONS

In this paper, we have evaluated the psychometric properties of a questionnaire designed to assess students' attitudes towards statistics. The questionnaire has two subscales, an affective and other evaluative, both with two-dimensional structure. In all cases, the Loevinger's scalability coefficients, H, are close to or above 0.4, indicating that the obtained factor structure is appropriate: the four empirical scales are significant, monotonous and consist of items that are added unidimensionally. Thus, the estimate scales can be used as a substitute for latent scales in the study of affective and evaluative components that influence students' attitudes towards statistics.

Globally, the results confirm a model that can offer guidance about how educators can reduce students' level of anxiety with respect to statistics. Specifically, if educators can familiarize their students about the social applications of statistics, this should reinforce their perception of the utility of this discipline for their current studies and increase their interest in studying the subject. These effects should indirectly translate into a reduction in the students' level of anxiety. Likewise, efforts to directly boost students' interest in statistics or their perception of its utility in their current studies should also reduce their level of anxiety.

Efforts to reduce the level of anxiety-nervousness should lead to improved academic performance in statistics among students, so this model could help educators design strategies to do this, or provide a means of evaluating the effectiveness of such strategies.

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REFERENCES

1. Auzmendi, E. (1992). *Las actitudes hacia la matemática-estadística en las enseñanzas medias y universitarias*. Bilbao: Mensajero.
2. Bayot, A.; Mondéjar, J.; Mondéjar, J.A.; Monsalve, F. and Vargas, M. (2005). The Difficulties of Learning Concepts in the Social Sciences. In Misztal, M. and M. Trawinski (eds.) *Studies in Teacher Education: Psychopedagogy*, 242-258. Kraków: Wydawnictwo Naukowe Akademii Pedagogicznej.
3. Beins, B.C. (1985). Teaching the relevance of statistics trough consumer-oriented research. *Teaching of Psychology*, 12, 168-169.
4. Carmona, J. (2004). Una revisión de las evidencias de fiabilidad y validez de los cuestionarios de actitudes y ansiedad hacia la estadística. *Statistics Education Research Journal*, 3(1), 5-28.
5. Darias, E. (2000). Escala de actitudes hacia la estadística. *Psicothema*, 12 (2), 175-178.
6. DeVellis, R. F. (2003). *Scale development: Theory and applications*, Second edition. Thousand Oaks, CA: Sage Publications.
7. Elosua, P. (2006). Modelo de doble monotonía fuerte para ítems politómicos aplicado a una escala de autoconcepto social. Propiedades formales y métricas. *Revista electrónica de metodología aplicada*, 11(1), 1-15.
8. Gil, J. (1999). Actitudes hacia la estadística. Incidencia de las variables sexo y formación previa. *Revista española de pedagogía*, LVII, 214, 567-590.
9. Junker, B. W. and Sijtsma, K. (2000). Latent and Manifest Monotonicity. *Applied Psychological Measurement*, 24, 65-81.
10. Katz, B. M. and Tomazic, T. Z. (1988). Changing student's attitudes toward statistics through a nonquantitative approach. *Psychological Reports*, 62, 658.
11. Mokken, R. J. (1971). *A theory and procedure of scale analysis*. The Hague, The Netherlands: Mouton.
12. Mokken, R. J. (1997). Nonparametrics models for dichotomous responses. In W. J. van der Linden and R. K. Hambleton (Eds.). *Handbook of Modern Item Response Theory*. New York, USA: Springer.
13. Mokken, R. J. and Lewis, C. (1982). A non parametric approach to the analysis of dichotomous item responses. *Applied Psychological Measurement*, 6, 417-430.
14. Mondéjar, J. and Vargas, M. (2010). Determinant factors of attitude towards quantitative subjects: Differences between sexes. *Teaching and Teacher Education*, 26(3), 688-693.
15. Mondéjar, J.; Vargas, M. and Bayot, A. (2008). Medición de la actitud hacia la estadística. Influencia de los procesos de estudio. *Revista Electrónica de Investigación Psicoeducativa*, 6 (3), 729-748.
16. Moolenaar, W. and Sijtsma, K. (2000). *MSP5 for windows*. Groningen: iecProGAMMA.
17. Roberts, D. M. and Saxe, J. E. (1982). Validity of a statistics attitude survey: a follow-up study. *Educational and Psychological Measurement*, 42, 907-912.
18. Schau, C., Stevens, J., Dauphinee, T. L. and Del Vecchio, A. (1995). The Development and Validation of the Survey of Attitudes toward Statistics. *Educational and Psychological Measurement*, 55 (5), 868-875.
19. Seipp, B. (1991). Anxiety and academic performance: A meta-analysis of findings. *Anxiety Research*, 4, 27-41.

20. Sijtsma, K. and Hemker, B. T. (1998). Nonparametric Polytomous IRT models for invariant item ordering, with results for parametric models. *Psychometrika*, 63(2), 183-200.
21. Sijtsma, K. & Molenaar, I. W. (2002). *Introduction to Nonparametric Item Response Theory*. Thousand Oaks, CA.: Sage.
22. Sijtsma, K. and Verwey, A. (1992). Mokken scale analysis; theoretical considerations and an application to transitivity tasks. *Applied Measurement in Education*, 5(4), 355-373.
23. Van Abswoude, A., Van der Ark, L. and Sijtsma, K. (2004). A Comparative Study of Test Data Dimensionality Assessment Procedures Under Nonparametric IRT Models. *Applied Psychological Measurement*, 28, 3–24.
24. Waters, L. K., Martelli, T. A., Zakrajsek, T. and Popovich, P. M. (1988). Factor analyses of two measures of attitudes toward statistics. *Educational and Psychological Measurement*, 48, 1037-1041.
25. Wise, S. (1985). The development and validation of a scale measuring attitudes toward statistics. *Educational and Psychological Measurement*, 45, 401-405.